Magnetic Fields & Electromagnetism

AP Physics C: E&M ▪ Unit 12

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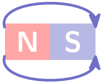
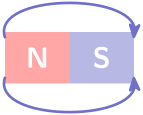


What we will cover

1. Magnetic fields
2. Force on a moving charge
3. Fields of current-carrying wires
4. Ampère's law



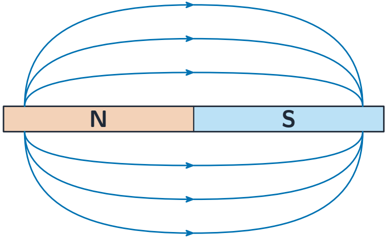
Magnetic fields

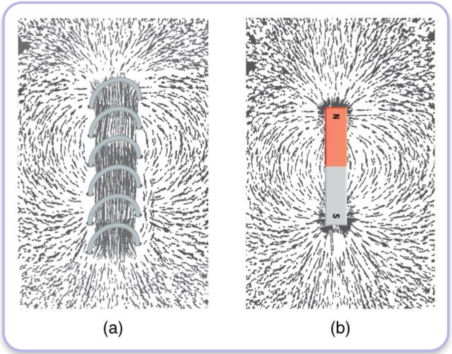
A **magnetic field** 磁场 $\vec{B}$ has field lines in closed loops – there are **no monopoles** 磁单极子. Materials differ by how their **atomic dipoles** 原子磁偶极子 align:

- **ferromagnetic** 铁磁性 – align strongly, stay (iron)
- **paramagnetic** 顺磁性 – align weakly
- **diamagnetic** 抗磁性 – weakly oppose

aurora Magnetism

Magnetic fields





solenoid Filings

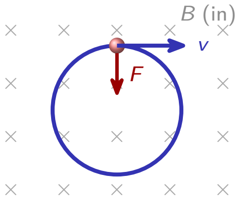
Force on a moving charge

A cross product

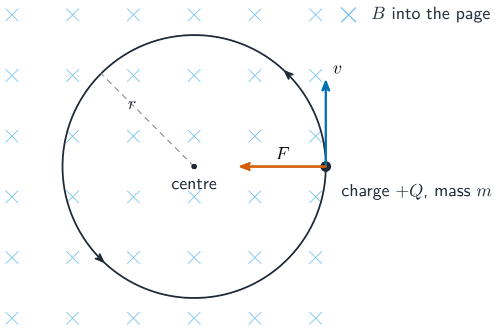
$$\vec{F} = q\,\vec{v} \times \vec{B}$$

Size $qvB\sin\theta$; $\perp$ to $\vec{v}$, so it does no work. A wire feels $\vec{F} = I\vec{L} \times \vec{B}$.

Perpendicular entry $\Rightarrow$ a circle:
$qvB = \dfrac{mv^2}{r}$, so $r = \dfrac{mv}{qB}$.



Force on a moving charge



$$BQv = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{BQ}$$

Fields of current-carrying wires

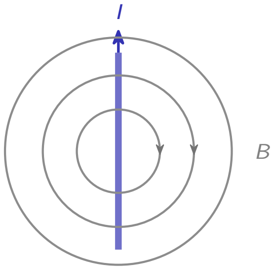
Moving charge makes magnetic field:

Biot-Savart law

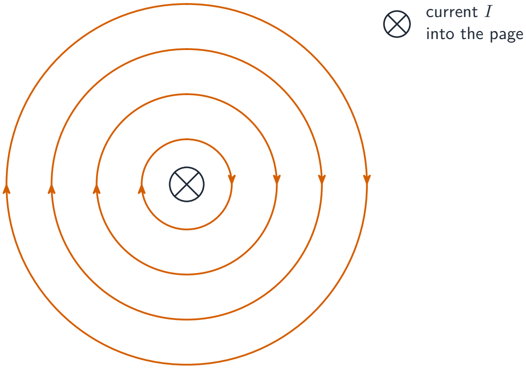
$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\, d\vec{l} \times \hat{r}}{r^2}$$

Integrate for standard results:

- long straight wire: $B = \dfrac{\mu_0 I}{2\pi r}$
- loop centre: $B = \dfrac{\mu_0 I}{2R}$



Fields of current-carrying wires



circular field lines (right-hand grip rule)

Ampère's law

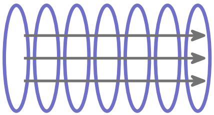
For enough symmetry, Ampère's law beats integrating Biot-Savart:

The loop integral

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$$

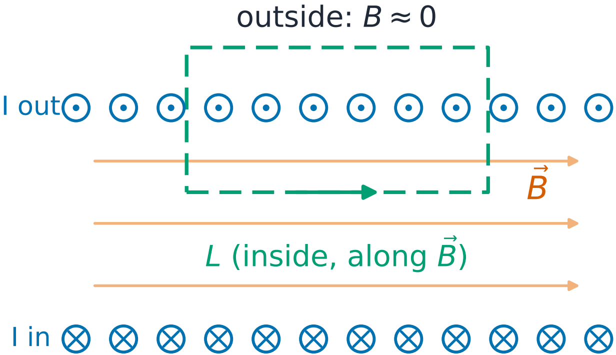
> Choose an **Amperian loop** 安培环路 where B is constant and parallel, so the integral becomes $B\times$ length.

Inside a **solenoid** 螺线管: $B = \mu_0 nI$, uniform.



$B = \mu_0 nI$

Ampère's law



Unit 12 – key takeaways

1 Fields

lines in closed loops; no magnetic monopoles

2 Force

$\vec{F} = q\vec{v} \times \vec{B}$, does no work; circle $r = mv/qB$

3 Wire fields

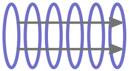
Biot-Savart; long wire $\mu_0 I/2\pi r$

4 Ampère

$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$; solenoid $\mu_0 n I$

Check yourself

1. Why does the magnetic force on a moving charge do no work?
2. Which law gives the field of a symmetric current quickly?
3. Double the distance from a straight wire – what happens to B?
4. Is the field inside an ideal solenoid uniform?



Answers **1.** it is perpendicular to $\vec{v}$ **2.** Ampère's law **3.** it halves **4.** yes